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Review Article—

Avian Influenza in North and South America, the Caribbean, and Australia, 2006–2008

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SUMMARY. Between 2006 and 2008, only one outbreak of highly pathogenic notifiable avian influenza (AI) was reported from the Americas, the Caribbean, and Australia. The outbreak, caused by H7N3, occurred in September 2007 in a multiage broiler breeder facility (~49,000 birds) near Regina Beach in southern Saskatchewan, Canada. The disease was confined to a single farm; the farm was depopulated. All other reports of infections in poultry or wild birds involved low pathogenicity AI viruses. A notable event that occurred during the 3-yr period was the spread of low pathogenicity notifiable AI (LPNAI) H5N2 (Mexican lineage) into the Caribbean countries of the Dominican Republic and Haiti in 2007 and 2008, respectively, representing the first detection of AI reported in these countries. Mexico reported that the LPNAI H5N2 virus continued to circulate in the central regions of the country, and a total of 49 isolations were made from 12 states between 2006 and 2008. Also, during this period there was a significant increase in AI surveillance in many countries throughout the Americas, the Caribbean, and Australia, resulting in the detection of AI subtypes H1 through H12 and N1 through N9 in domestic bird species (chickens, turkeys, guinea fowl, upland game birds, and ducks/geese). The United States was the only one of these countries that reported detections of LPNAI (H5 or H7) infections in commercial poultry: one in chickens (H7N3, 2007), two in turkeys (H5N1 and H5N2, 2007), and one in pheasants (H5N8, 2008). Detections of AI viruses in wild birds between 2006 and 2008 were reported from North America (Canada and the United States), South America (Bolivia, Argentina, Chile, and Brazil), and Australia.

RESUMEN. *Estudio Recapitulativo*—Influenza aviar en Norte y Sur América, el Caribe y Australia, 2006–2008.

Entre el año 2006 y el 2008, solamente se reportó un brote notificable de influenza aviar de alta patogenicidad en el continente Americano, El Caribe y Australia. El brote, causado por el subtipo H7N3, que ocurrió en septiembre del 2007 en las instalaciones de una granja con edades múltiples de reproductoras pesadas (aproximadamente 49,000 aves) cerca de Regina Beach al sur de Saskatchewan, Canadá. La enfermedad se limitó a una sola granja; la cual fue despoblada. Todos los demás reportes de las infecciones en aves comerciales o aves silvestres estuvieron relacionados con virus de influenza aviar de baja patogenicidad. Un evento destacable que ocurrió durante el período de tres años, fue la diseminación del virus de la influenza aviar de baja patogenicidad reportable (LPNAI, por su siglas en inglés) H5N2 (perteneciente al linaje mexicano), en los países caribeños República Dominicana y Haití en el 2007 y el 2008, respectivamente; lo que representa la primera detección del virus de la influenza aviar en estos países. México reportó que el virus de baja patogenicidad H5N2 continuó circulando en las regiones centrales de ese país, y se obtuvieron un total de 49 aislamientos en 12 estados entre los años 2006 y 2008. También, durante este período hubo un incremento significativo en los muestreos de vigilancia de influenza aviar en muchos países a lo largo del continente americano, el Caribe y Australia, lo que resultó en la detección en especies de aves domésticas (pollos, pavos, gallinas de Guinea, gallos de pelea en Norte América, y patos y gansos) de subtipos del virus de influenza aviar H1 al H12 y N1 al N9. Estados Unidos fue el único de estos países que reportó la detección de infecciones con virus de baja patogenicidad (H5 ó H7) en aves comerciales: uno en pollos (H7N3, en el 2007), dos en pavos (H5N1 y H5N2, en el 2007), y uno en faisanes (H5N8, en el 2008). Las detecciones de los virus de influenza aviar en aves silvestres entre los años 2006 y 2008 fueron reportadas en Norte América (Canadá y Estados Unidos), en América de Sur (Bolivia, Argentina, Chile, y Brasil), y en Australia.

Key words: avian influenza, highly pathogenic notifiable avian influenza, low pathogenicity avian influenza, low pathogenicity notifiable avian influenza, poultry, surveillance, wild birds

Abbreviations: AI = avian influenza; AIV = avian influenza virus; HA = hemagglutinin; HPNAI = highly pathogenic notifiable avian influenza; LBMS = live bird marketing system; LPAI = low pathogenicity avian influenza; LPNAI = low pathogenicity notifiable avian influenza; NA = neuraminidase; NAAHLN = North American Animal Health Laboratory Network; NVSL = National Veterinary Services Laboratories; OIE = World Organization for Animal Health; rRT-PCR = real-time reverse transcription–PCR

INTRODUCTION

This report describes avian influenza (AI) virus detections in domestic poultry and wild birds in North and South America, the Caribbean, and Australia during the period ranging from 2006 to 2008, with emphasis on detections in domestic poultry. Information on highly pathogenic notifiable avian influenza (HPNAI) and low pathogenicity notifiable AI (LPNAI) was obtained from reports to the World Organization for Animal Health (OIE) (3) and through personal communication. However, gathering information on the occurrences of outbreaks of nonnotifiable low pathogenicity avian influenza (LPAI) was difficult, because there was no centralized source of surveillance information. Some countries in the region might have AI surveillance programs in place, but the information

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was not available for inclusion in this report. Reports of AI from the United States were obtained from the Proceedings of the U.S. Animal Health Association (8) or from testing performed at the National Veterinary Services Laboratories (NVSL), a National Reference Laboratory for the U.S. Department of Agriculture and an international reference laboratory for the OIE. Results on wild bird surveillance presented here are not covered by other authors in this supplemental issue of *Avian Diseases*. Results of wild bird surveillance in the United States will only focus on isolations of H5 and H7 subtypes.

HIGHLY PATHOGENIC NOTIFIABLE AVIAN INFLUENZA IN CHICKENS

The only report of HPNAI in the Americas, the Caribbean, and Australia during 2006–08 came from Canada. In September 2007 a multiage chicken breeding facility located near the town of Regina Beach in Southern Saskatchewan was diagnosed with HPAI H7N3 avian influenza virus (AIV). The flock of 49,100 birds was located in multiple houses containing roosters, 10-wk-old pullets, and 29- and 52-wk-old breeding hens. The disease was first detected in the rooster barns, where mortality eventually reached 90%. The disease also spread to the barns housing 29-wk-old breeder hens. The H7N3 virus was shown to have an insert of six amino acids at the hemagglutinin (HA) cleavage site and an intravenous pathogenicity index of 3.0 (J. Pasick, pers. comm.). Details of the outbreak will be presented by other authors in this supplemental issue of *Avian Diseases*.

LPAI IN CHICKENS

LPAI virus infections in chickens during the 2006–2008 period were reported by seven countries: Australia, Brazil, Canada, the Dominican Republic, Haiti, Mexico, and the United States. A list of the virus subtypes isolated or specific antibodies detected is shown in Tables 1 and 2, respectively.

Australia. In Australia, AI surveillance in poultry is accomplished primarily via a well-developed passive surveillance system, through which flock records (performance, morbidity, mortality, drop in egg production, etc.) are routinely monitored by company service personnel, livestock managers, and veterinarians for evidence indicative of AI. The only detection of AIV in chickens in Australia occurred in 2006, when a LPAI H6N4 virus was isolated from a small flock of chickens in Queensland. Also, in 2006, active AI sero-surveillance was carried out on 180 farms (broilers, layers, breeders), which represented approximately 9% of commercial poultry farms in Australia. There was no evidence of H5 or H7 AIV infection by the active surveillance testing.

Brazil. In 2006 and 2007, approximately 60,000 specimens in more than 2050 poultry submissions were tested by enzyme-linked immunosorbent assay, agar gel immunodiffusion, virus isolation, or real-time reverse transcription–PCR (rRT-PCR; 2008 only), all with negative results. An additional 1200 swab pools were collected from wild birds and backyard chicken flocks near wild bird testing sites, from which four LPAI H3 viruses (N subtype not determined) were isolated from chickens and three from wild birds (see ''AI in wild birds'' section for details). In 2007, active surveillance also was carried out on 269 chicken breeder flocks and spent layer farms; no AI infection was identified.

Canada. AI surveillance in Canada was primarily accomplished through passive surveillance, although an active sero-surveillance program was initiated in 2008, resulting in the testing of approximately 14,000 serums. In 2008, H6N8 AIV was isolated from a chicken breeder flock in Ontario that experienced a drop in egg production.

Dominican Republic and Haiti. AI was detected for the first time in the Caribbean in 2007. In December 2007, antibodies to H5N2 were detected in sera submitted for AI testing from the Dominican Republic. Since that time, active surveillance detected virus and/or antibodies to LPNAI H5N2 in a total of 11 premises involving 871 birds (3). In June 2008, LPNAI H5N2–infected birds also were found in Haiti, which shares a common border with the Dominican Republic. Infections in the Dominican Republic and Haiti have been detected primarily in live-bird markets, village poultry, and fighting cocks. The H5N2 viruses in the Dominican Republic and Haiti were shown to be closely related to the Mexican lineage of H5N2, which has been circulating in Mexico since early 1994 (pers. obs.).

Mexico. A LPNAI H5N2 virus has been circulating in poultry in Mexico since 1994. In December 1994 the virus mutated to HPNAI and was eradicated by the end of 1995. Control efforts since 1995 have centered on the use of H5N2 inactivated vaccine and, since 1997, an H5-fowl pox vectored vaccine. From 2006 to 2008, the LPNAI H5N2 virus was detected in 49 flocks in 12 states (Table 1). Thirteen flocks were positive for the H5 virus in 2006, two in 2007, and 34 flocks in 2008. The majority of isolates have come from states in Central Mexico. Recently it was discovered that the current rRT-PCR assay used to detect North American strains of H5 was no longer detecting all of the recent H5N2 isolates from Mexico. Modifications to the current H5 rRT-PCR assay are being addressed as a cooperative effort of the North American Animal Health Laboratory Network (NAAHLN) involving Mexico, Canada, and the United States. The NAAHLN was formed as an outgrowth of the Security and Prosperity Partnership signed in 2005 by the leaders of the three countries. The purpose of the NAAHLN is to harmonize diagnostic tests for AI to ensure that AI can be detected quickly and accurately.

United States. Since 2006, surveillance for AIV in commercial poultry has been conducted under provisions of the National H5 and H7 Low Pathogenicity Avian Influenza Control Program administered through the National Poultry Improvement Plan (1), as well as through a passive surveillance program. From 2006 to 2008, AI surveillance in chickens in the United States detected nine HA (H1–H3, H5–H8, H10, and H11) and six neuraminidase (NA; N1–N4, N7, and N8) subtypes of AI virus and/or specific antibodies from 15 states (Tables 1, 2). Most of the infections were detected in live bird marketing systems (LBMS) and small-holder premises. However, one outbreak of LPNAI H7N3 occurred in June 2008 in a flock of commercial chickens in Arkansas. The flock (two houses) of 16,000 65-wk-old broiler breeders tested positive for antibodies to H7N3 during routine pre-slaughter testing. No clinical signs were seen in the flock at the time of testing. An H7N3 virus was isolated from the flock and shown to be LPNAI, most closely related to North American H7 viruses circulating in wild waterfowl. The premises were depopulated, cleaned, and disinfected.

LPAI IN TURKEYS

The only reports of LPAI infections in turkeys in the Americas came from Canada and the United States.

Canada. During 2006 to 2008, Canadian animal health officials reported a total of three detections of AI in turkeys, all with a history

of drop in egg production. A LPAI H3N2 virus was isolated from two flocks of turkeys, one in 2006 in Manitoba and one in 2007 in Ontario. Additionally, a LPAI H6N1 virus was isolated from a turkey breeder flock from Ontario in 2006 (Table 1). The H3N2 viruses were shown to be similar to swine H3N2 viruses that had been circulating in Canada and the United States in recent years (J. Pasick, pers. comm.).

United States. During the 2006–08 period, active and passive surveillance for AI infections in turkeys in the United States detected virus or antibodies to eight HA (H1–H7 and H10) and eight NA (N1, N2, N4, N5, and N7–N9) subtypes from 20 states (Tables 1, 2). Three of the detections involved LPNAI in commercial meat turkeys in three states: Nebraska, Virginia, and West Virginia. The West Virginia detection occurred in April 2007 and involved a single flock of 25,600 turkeys. Routine pre-slaughter AI surveillance testing resulted in detection of antibodies to the H5N2-subtype AIV. Additional specimens collected from the flock were positive for H5-specific RNA by rRT-PCR, but no virus was isolated in embryonating chicken eggs. Sequencing of the RNA from the clinical specimen showed that the cleavage site of the H gene was consistent with that of LPNAI H5 virus. The premises was depopulated, cleaned, and disinfected. The detection of LPNAI in Nebraska occurred in June 2007 and involved a multiage turkey operation of 145,000 birds. Antibodies to H7N9-subtype AIV were initially detected in serum samples collected at slaughter. Subsequent testing of younger birds on the premises showed the presence of AI-specific RNA by rRT-PCR in swab specimens, and a LPNAI H7N9 virus was isolated in embryonating chicken eggs. The flock was disposed of by controlled marketing of virus-negative flocks. Additional surveillance of flocks in surrounding premises did not detect any spread of the virus. The third detection of LPNAI occurred in a flock of 54,000 turkeys in Virginia in July 2007. Initially, H5N1-specific antibodies were detected in routine pre-slaughter AI surveillance serum samples. Subsequent testing showed H5 RNA in clinical specimens by rRT-PCR, and LPNAI H5N1 (North American lineage) virus was isolated from additional specimens collected at depopulation. Surveillance of poultry in surrounding premises did not detect additional infections.

In addition to the three detections of LPNAI in turkeys reported to the OIE in 2007, active surveillance resulted in the detection of AIV-specific antibodies to H7N9 in a single flock of turkeys in Minnesota (at slaughter; 2007) and antibodies to H6N2 in a single flock of turkeys in South Dakota (2006). Epidemiologic investigation of these seropositive findings demonstrated no evidence of the presence of AI virus.

AI IN GUINEA FOWL

The only reports of AI infections in guinea fowl during the period from 2006 to 2008 came from the United States. Isolations of LPNAI H5N2 virus were made on four occasions from swabs collected from guinea fowl (New Jersey and Oregon, 2007; New Jersey and New York, 2008) sampled as part of the LBMS surveillance, and in 2007 antibodies to H5N2 virus were detected in guinea fowl in a premises in Ohio, where H5N2 antibody–positive ducks were also found. The birds on the Ohio premises were being tested to meet interstate movement requirements. Swabs collected from birds on the Ohio premises were negative for H5-specific RNA by rRT-PCR, and no virus was isolated. Surveillance also detected five additional HA subtypes (H3, H4, H6, H10, and H11) and three NA subtypes (N2, N7, and N8) in guinea fowl in six states (Tables 1, 2).

AI IN DOMESTIC DUCKS AND GEESE

Canada. Two LPAI viruses were isolated from domestic ducks or geese in Ontario, Canada, in 2006. A LPAI H3N8 virus was isolated from a maned goose (*Chenonetta jubata*) imported from the Netherlands that died in quarantine. The second isolation, a LPAI H2N5 virus, was from a Muscovy duck.

United States. Surveillance activities in the United States detected AI virus or specific antibodies to 11 HA (H1–H7 and H9–H12) and all nine NA subtypes in domestic ducks and/or geese from 17 states (Tables 1, 2). Some of the infected ducks were raised for release into hunting preserves, but the majority of the positive ducks were in the Northeast United States. In 2007, antibodies to H4N2 and H5N2 were detected in ducks in Ohio when they were tested for interstate movement. No virus was isolated from the ducks; surveillance of nearby farms was negative for AI.

AI IN UPLAND GAME BIRDS

The farming of upland game birds (pheasants, quail, chucker partridges, etc.) in North America is increasing because of demand from hunting preserves. During the 2006–2008 period, AI infections in upland game birds were reported from Canada and the United States.

Canada. In 2008, AI surveillance in upland game birds resulted in the isolation of a LPAI H3N2 virus from Japanese quail with clinical disease (Table 1). Bacterial pathogens were also detected in the quail flock. The virus was shown to be similar to viruses previously isolated from pigs and turkeys in Canada and the United States (J. Pasick, pers. comm.).

United States. In the United States, AI surveillance of upland game birds is conducted according to Subpart E of the National Poultry Improvement Plan. During the 2006–2008 period, AI surveillance in these populations resulted in the detection of eight HA (H2–H6, H9, H10, and H12) and four NA (N2, N6, N7, and N8) subtypes from six states (Tables 1, 2). One of the detections (2008) involved a commercial breeding and raise-for-release facility in Idaho. The facility housed approximately 30,300 birds (pheasants, ducks, quail, chukars, and pigeons) and was involved in interstate sales. The virus was first detected when three pheasant carcasses, submitted to the Pennsylvania State University diagnostic laboratory, were found to be positive for H5 AIV, *Pasteurella*, and *Mycoplasma*. Additional specimens collected from the flock yielded a LPNAI H5N8 virus and antibodies specific to H5N8 in the pheasants and mallard ducks and a LPAI H4N7 virus in the ducks. Surveillance of surrounding premises and tracebacks from the positive premises were negative for additional AI virus infection. The premises were depopulated, cleaned, and disinfected.

AI IN CAGED PET BIRDS

United States. The only report of AI in caged pet birds came from the United States, where a LPNAI H5N2 virus was isolated from a yellow-headed Amazon parrot (*Amazona oratrix*) in July 2007. The parrot was confiscated by U.S. Customs officials at the U.S./Mexico border at San Ysidro, CA (Table 1).

AI IN WILD BIRDS

Since 2005, there has been a significant increase in wild bird surveillance in the Americas, the Caribbean, and Australia because of

Table 1. Subtypes of avian influenza virus isolated from North and South America, the Caribbean, and Australia from 2006 to 2008. All viruses were characterized as low pathogenicity viruses, unless otherwise indicated. Postal codes were used for states and provinces.

Subtype	Host(s)	Country (state/province)	Year(s)
H1N1	Avian (unknown)	U. S. A. (PA)	2007
	Duck	U. S. A. (RI)	2007
	Duck (Muscovy), environment	U. S. A. (NJ, NY)	2008
H2	Chicken	U. S. A. (NC)	2006
H2N3	Chicken	U. S. A. (OH)	2007
	Duck	U. S. A. (FL, ID)	2006
	Environment	U. S. A. (PA)	2008
H2N4	Turkey	U. S. A. (CA)	2008
H2N5	Duck (Muscovy)	Canada (ON)	2006
H2N8	Turkey	U. S. A. (CA)	2008
H2N9	Duck	U. S. A. (ID)	2006
H3	Chicken	Brazil (PA, PE)	2007
	Wild bird	Brazil (PA)	2007
	Turkey	U. S. A. (MN)	2007
H3N2	Duck	U. S. A. (OH, PA)	2008
	Quail	Canada (QC)	2008
	Turkey	Canada (MB)	2006
	Turkey	Canada (ON)	2007
	Turkey	U. S. A. (MN, WI)	2008
	Waterfowl	U. S. A. (SD)	2006
H3N6	Duck	U. S. A. (NJ)	2008
H3N8	Avian (unknown)	U. S. A. (NJ)	2006
	Duck	U. S. A. (CA)	2006
	Duck	U. S. A. (PA)	2008
	Duck (wild)	Australia (TAS)	2006
	Environment	U. S. A. (NJ)	2007
	Goose (maned)	Canada (AB)	2006
	Waterfowl	U. S. A. (SD)	2006
H3N9	Duck (Muscovy)	U. S. A. (CT)	2008
H4N4	Duck	U. S. A. (OH)	2008
H4N6	Duck	U. S. A. (NY, VA)	2007
	Duck	U. S. A. (PA)	2006, 2007
	Duck (wild)	Australia (TAS)	2006
	Environment	U. S. A. (NY, PA)	2007
	Unknown	U. S. A. (CA, NJ)	2006
H4N7	Duck	U. S. A. (ID)	2008
H4N8	Duck	U. S. A. (ID)	2006
	Duck	U. S. A. (OH, PA)	2008
	Environment	U. S. A. (NJ)	2007
H5N1	Turkey	U. S. A. (VA)	2007
H5N2	Avian (unknown)	U. S. A. (NJ, NY)	2006
	Chicken	Dominican Republic	2008
	Chicken	Mexico (CH, HG, JA, QA, VZ), U. S. A. (NJ, NY)	2006
	Chicken	Mexico (SL)	2007
	Chicken	Mexico (CH, HG, EM, NA, PU, QA, TM, VZ, ZT), U. S. A. (NJ)	2008
	Duck	U. S. A. (NJ, NY, PA)	2006
	Duck	U. S. A. (NJ, NY, OH, OR, PA)	2007
	Duck	U. S. A. (NJ, NY, OH, PA)	2008
	Guinea fowl	U. S. A. (NJ)	2006
	Guinea fowl, environment	U. S. A. (NY, OR)	2007
	Guinea fowl, environment	U. S. A. (NJ, NY)	2008
	Pheasant	U. S. A. (PA)	2008
	Quail, turkey	U. S. A. (NY)	2007
	Avian (unknown)	U. S. A. (NY)	2006
	Pet bird (*Amazona oratrix*)	U. S. A. (CA)	2007
H5N3	Duck (wild)	Australia (VIC)	2008
H5N8	Avian (unknown)	U. S. A. (NJ)	2006
	Duck, pheasant	U. S. A. (ID)	2008
H5N9	Duck	U. S. A. (CA)	2006
	Duck	U. S. A. (PA)	2007
	Gull	Chile	2008
H6	Duck	U. S. A. (NJ, NY)	2006

Table 1. Continued.

Subtype	Host(s)	Country (state/province)	Year(s)
H6N1	Chicken	U. S. A. (IA, PA)	2006
	Duck	U. S. A. (DE, WA)	2006
	Environment	U. S. A. (PA)	2006
	Turkey	Canada (ON)	2006
H6N2	Chicken	U. S. A. (CA)	2006
	Chicken	U. S. A. (FL)	2008
	Duck	U. S. A. (FL)	2006
	Duck, environment	U. S. A. (OH, FL)	2008
	Quail	U. S. A. (CA)	2006
H6N4	Chicken	Australia (QLD)	2006
H6N5	Environment	U. S. A. (PA)	2007
	Turkey	U. S. A. (MN)	2008
H6N8	Chicken	Canada (ON)	2008
	Chicken, duck	U. S. A. (NY)	2006
	Environment	U. S. A. (NJ, NY)	2006
	Guinea fowl	U. S. A. (PA)	2006
	Turkey	U. S. A. (NJ)	2007
H7N2	Chicken	U. S. A. (NJ, NY)	2006
	Duck (wild)	Australia (TAS)	2006
	Environment	U. S. A. (NY)	2006
H7N3	Avian (unknown), chicken	U. S. A. (AR, CA)	2008
H7N3HP	Chicken	Canada (SK)	2007
H7N6	Duck (grey teal)	Australia (VIC)	2007
H7N7	Avian (unknown)	U. S. A. (CA)	2008
	Chicken	U. S. A. (NC, PA)	2008
	Turkey	U. S. A. (PA)	2008
H7N9	Turkey	U. S. A. (NE)	2007
H9N2	Duck	U. S. A. (NY)	2007
	Pheasant	U. S. A. (PA)	2007
H10N7	Duck	U. S. A. (PA)	2008
	Duck	U. S. A. (WA)	2006
	Goose	U. S. A. (AR)	2006
	Avian (unknown)	U. S. A. (NJ)	2006
	Avian (unknown)	U. S. A. (PA, NY)	2007
H11N2	Duck	U. S. A. (MA, PA)	2007
	Duck (Muscovy)	U. S. A. (MA)	2006
	Environment	U. S. A. (MA)	2007
	Guinea fowl, goose	U. S. A. (NJ)	2007
H11N9	Duck, environment	U. S. A. (PA)	2007
H12N5	Duck	U. S. A. (PA)	2007
	Duck	U. S. A. (OH)	2008
H13N2	Gull	Chile	2008
H13N6	Gull (silver)	Australia (TAS)	2006

the threat of HPNAI H5N1. The information presented here will only include detections that are not likely to be presented by other authors in this supplemental issue of *Avian Diseases*. However, this report will provide a summary of isolations of H5 and H7 AIVs recovered from wild birds in the United States and will not include results of extensive wild bird surveillance from Canada.

Australia. Between 2006 and 2008, extensive wild bird surveillance in Australia resulted in the isolation of six AI viruses from ducks and gulls, representing five HA (H3–H5, H7, and H13) and four NA (N2, N3, N6, and N8) subtypes (Table 1). Additionally, 28 specimens from ducks tested positive by H5 rRT-PCR, and four specimens tested positive by H7 rRT-PCR but were negative by virus isolation. Testing by rRT-PCR also detected subtypes H3, H4, H11, and H12, based on sequencing the PCR amplicon (P. Selleck, pers. comm.).

Central America. Surveillance for AI was conducted in the French Caribbean by a recently organized animal health network (CaribVET) located in Guadeloupe. The surveillance was sponsored by the French Agricultural Research Centre for International Development. In August 2007 and March 2008 more than 250 swab specimens from birds were tested by rRT-PCR; no detections of AI virus were made.

South America. Historically, reports of AI virus detections in wild birds in South America have been few. However, recent surveillance efforts have resulted in the detection of AI virus in wild birds. In 2006, Spackman *et al.* (6) reported on the isolation of a LPNAI H7N3 virus (isolated in 2001) from a cinnamon teal in Bolivia. The isolate was made from one of 93 birds sampled. Phylogenetic studies showed that the H7N3 virus from the cinnamon teal was the likely progenitor of the LPNAI H7N3 virus isolated in 2002 in Chile, which mutated to HPNAI virus (7).

Argentina reported testing between 5000 and 6000 specimens from wild birds in each of the years from 2006 through 2008. In 2008, Pereda *et al.* (4) reported on the isolation of an H13N9 virus from a gull (*Larus dominicanus*). Phylogenetic studies showed the H13 virus formed a separate genetic clade from other H13 viruses from North America, indicating that there may be a unique genetic lineage of H13 viruses circulating in gulls in South America. Pereda

Table 2. Avian influenza virus subtype-specific antibodies detected in serum from various sources in the United States and the Dominican Republic, 2006–2008. Postal codes were used for states.

Subtype	Host(s)	Country (state/province)	Year(s)
H1	Chicken	U. S. A. (PA)	2006
	Chicken	Dominican Republic	2008
	Turkey	U. S. A. (IA, IL, IN, MN, NC, OH)	2006
	Turkey	U. S. A. (AR, IA, IL, MI, MN, NC, OH, SD)	2007
	Turkey	U. S. A. (AR, IA, MI, MN, NC, OH, SD, VA)	2008
	Duck	U. S. A. (PA)	2007
	Ostrich	U. S. A. (PA)	2008
H1N1	Chicken	U. S. A. (SD)	2008
	Turkey	U. S. A. (CA, IA, NC, OH)	2006
	Turkey	U. S. A. (IA, IL, MN, NC, OH)	2007
	Turkey	U. S. A. (IA, MN, NC, OH, SD)	2008
H1N2	Turkey	U. S. A. (OH, SC)	2006
	Swan	U. S. A. (MI)	2006
H2	Turkey	U. S. A. (IL)	2006
	Turkey	U. S. A. (OH)	2008
	Duck, pheasant	U. S. A. (ID)	2006
H2N3	Duck	U. S. A. (FL)	2006
H3	Chicken	U. S. A. (FL, IA, MA, MN)	2006
	Chicken	U. S. A. (IA)	2007
	Chicken	Dominican Republic	2008
	Turkey	U. S. A. (IA, IL, IN, MN, NC, OH)	2006
	Turkey	U. S. A. (AR, IA, IL, MI, MN, NC, OH, SD, WI)	2007
	Turkey	U. S. A. (AR, IA, MI, MN, NC, OH, SD, VA, WI)	2008
H3N1	Turkey	U. S. A. (MN, NC, OH)	2006
	Turkey	U. S. A. (OH)	2007, 2008
H3N2	Chicken	U. S. A. (IA, MN)	2006
	Chicken	U. S. A. (SD)	2008
	Turkey	U. S. A. (AR, IA, IL, IN, MI, MN, NC, OH)	2006
	Turkey	U. S. A. (IA, IN, MN, NC, SC, SD, WI)	2007
	Turkey	U. S. A. (IA, IL, IN, MN, MO, NC, ND, OH, SD, WI)	2008
	Pheasant	U. S. A. (MN)	2007
	Quail	U. S. A. (CA)	2006
H3N8	Guinea fowl	U. S. A. (IL)	2006
H4	Turkey	U. S. A. (WI)	2008
	Guinea fowl	U. S. A. (OH)	2007
	Duck	U. S. A. (CA)	2006
	Duck	U. S. A. (PA)	2007
H4N2	Guinea fowl	U. S. A. (OH)	2007
H4N6	Quail, duck	U. S. A. (CA)	2006
H5	Chicken	U. S. A. (NC)	2008
	Pheasant, quail	U. S. A. (MA)	2006
H5N1	Turkey	U. S. A. (VA)	2007
H5N2	Chicken	U. S. A. (PA)	2007
	Chicken	Dominican Republic, U. S. A. (MA)	2008
	Pheasant	U. S. A. (MA)	2008
	Turkey	U. S. A. (WV)	2007
	Guinea fowl, duck	U. S. A. (OH)	2007
	Quail	U. S. A. (NY)	2007
H6	Chicken	U. S. A. (FL, NH)	2008
	Turkey	U. S. A. (SD)	2008
	Swan (black)	U. S. A. (FL)	2008
H6N1	Chicken	U. S. A. (MN)	2008
H6N2	Turkey	U. S. A. (SD)	2006
	Pheasant	U. S. A. (NY)	2006
H6N5	Turkey	U. S. A. (SD)	2008
H6N8	Guinea fowl	U. S. A. (NH)	2006
H7	Chicken	U. S. A. (MA)	2006
	Chicken	U. S. A. (NH)	2008
	Duck	U. S. A. (NC)	2008
H7N3	Chicken	U. S. A. (AR)	2008
H7N7	Chicken	U. S. A. (NC, NH)	2008
H7N9	Turkey	U. S. A. (MN, NE)	2007
H8N2	Ostrich	U. S. A. (NY)	2008
H8N4	Chicken	U. S. A. (MD)	2006
H9N2	Quail, duck	U. S. A. (CA)	2006

Table 2. Continued.

Subtype	Host(s)	Country (state/province)	Year(s)
H10	Chicken	U. S. A. (FL, PA)	2006, 2007
	Turkey	U. S. A. (SD)	2008
H10N3	Turkey (wild)	U. S. A. (MD)	2008
H10N7	Chicken	U. S. A. (NE)	2006
	Turkey	U. S. A. (SD)	2008
	Guinea fowl	U. S. A. (KY)	2007
	Pheasant	U. S. A. (PA)	2007
H11	Chicken	U. S. A. (PA)	2007
H11N2	Ostrich	U. S. A. (FL)	2008
H12	Pheasant, duck	U. S. A. (ID)	2006
H12N8	Duck	U. S. A. (FL)	2006

also reported that 12 of the specimens tested positive by rRT-PCR but were negative by virus isolation. Subtyping of the rRT-PCR–positive specimens was not reported.

Surveillance in wild birds in Chile detected two AI viruses from gulls: a LPNAI H5N9 virus was isolated in 2008 (*L. dominicanus*), and an H13N6 virus was isolated in 2007 (*Larus pipixcan*).

Brazil reported isolation of three LPAI H3 viruses from approximately 1200 samples collected during 2006 and 2007. The isolations were made from a ruddy turnstone (*Arenaria macularia*), a gull (*L. domenicanus*), and a sandpiper (*Calidris pusilla*).

Uruguay reported testing a total of 181 specimens from wild birds, with negative results.

United States. Between 2006 and 2008, over 330,000 swab specimens from wild birds were collected and tested by rRT-PCR in an interagency surveillance program to detect HPNAI H5N1 virus in wild birds. Specimens were collected from all 50 states in each of the 3 yr. All specimens found positive by rRT-PCR for H5 or H7 at local testing laboratories were confirmed by the NVSL, where virus isolation and characterization were performed. Details of the surveillance will be covered by other authors in this supplemental issue of *Avian Diseases*; however, a brief summary of H5 and H7 detections will be presented here (Table 1). LPNAI H5N1 virus (North American lineage) was isolated all 3 yr in 10 states (Delaware [2006, 2007], Iowa [2008], Illinois [2006], Maryland [2006, 2007], Michigan [2006, 2007], Minnesota [2007, 2008], Montana [2007], New Jersey [2007], Tennessee [2008], and Wyoming [2008]). Other LPNAI H5 viruses isolated from wild birds are as follows: H5N2 ($n = 169$, 36 states), H5N3 ($n = 30$, 16 states), H5N4 ($n = 1$), H5N5 ($n = 1$), H5N7 ($n = 1$), H5N8 ($n = 4$, three states), and H5N9 ($n = 7$, five states). The H5-subtype viruses were isolated in 36 of 50 (72%) states during the 3 yr. Viruses of the H7 subtype were isolated from 101 specimens and were detected in 31 of 50 (62%) states. The H7-subtype viruses isolated from wild birds are as follows: H7N1 ($n = 8$, five states), H7N2 ($n = 5$, five states), H7N3 ($n = 68$, 26 states), H7N4 ($n = 2$, two states), H7N6 ($n = 5$, four states), H7N7 ($n = 6$, four states), H7N8 ($n = 3$, three states), and H7N9 ($n = 4$, four states).

DISCUSSION

There is little doubt that surveillance for AI worldwide, and more specifically in the Americas, the Caribbean, and Australia, is at historic levels, driven by the threat of introduction of HPNAI H5N1 and the concerns that the virus has pandemic potential. In previous summaries of AI virus infections in poultry in the Western Hemisphere, the vast majority of the reports came from Canada, Mexico, and the United States, with a few additional reports from Central and South America. However, this has changed, and most countries in South America and the Caribbean are now conducting AI surveillance in poultry or wild birds at some level. As a result, AI detections were reported from countries with no previous information on AI, but surveillance in many countries is still inconsistent, and the collection of surveillance data is difficult. Also, release of the data by governments is often restricted as a result of concerns about the potential negative impact on the trade of poultry and poultry products.

The single detection of HPNAI (H7N3) in Canada seems insignificant compared to the number of outbreaks of HPNAI H5N1 reported in Asia, Europe, the Middle East, and Africa during the same period. However, the Canadian outbreak had one interesting feature: the HPNAI H7N3 virus responsible for the outbreak acquired virulence through the insertion of a six–amino acid segment near the HA cleavage site, possibly as a result of recombination from an unknown source. Recombination was reported to be responsible for the emergence of two additional HPNAI H7N3 viruses from outbreaks in Chile in 2002 and Canada in 2004 (2,7). Since 2002, the phenomenon of recombination has only been reported with H7N3 viruses in the Western Hemisphere. Interestingly, 68% (68 of 101 isolates) of LPNAI H7 viruses isolated in wild bird surveillance conducted in the United States from 2006 to 2008 were H7N3 viruses. It is not known if the H7N3 viruses also were the predominant subtype isolated in surveillance of wild birds in Canada before the outbreak occurred.

Between 2006 and 2008, HA subtypes H1 through H12 and all nine NA subtypes were detected in domestic poultry in the Americas, the Caribbean, and Australia. Similar findings were reported from wild bird surveillance during which HA subtypes H1 through H13 and H16 have been found in North America (5,9). Subtypes H14 and H15 have not yet been detected in the Western Hemisphere. In the United States, LPNAI H5 and H7 viruses were isolated from wild birds in 36 of 50 (72%) and 31 of 50 (62%) states, respectively. Since the AI viruses detected in poultry are a reflection of what is found in wild birds, control efforts should focus on separation of domestic poultry from wild aquatic birds to reduce the likelihood of introduction of AI viruses into poultry operations.

The disproportionate number of reports from the United States compared to other countries in the Americas, the Caribbean, and Australia makes it appear that AI is common in poultry in the United States. However, the high number of detections more likely reflects the intense level of active and passive surveillance conducted in U.S. commercial poultry and small-holder farms and in the LBMS rather than a higher incidence. In each of the 3 yr (2006–2008), approximately three million tests were performed using type-

specific tests such as the agar gel immunodiffusion, enzyme-linked immunosorbent assays, rRT-PCR, and antigen capture immunoassays at state and industry laboratories. All positive specimens and AI virus isolates are submitted to the U.S. Department of Agriculture's National AI Reference Laboratory (NVSL, Ames, IA) for subtyping and characterization. The incentive for participation in AI surveillance was provided by the establishment, in 2006, of the National Low Pathogenicity H5 and H7 Control Program (1). This voluntary program pays 100% indemnity for participating states that meet certain criteria. Following the adoption of the control program the commercial poultry industry, in cooperation with the states and the Federal Government, set in place a program to test 100% of commercial flocks prior to slaughter or movement from a premises. The vast majority of detections have been found in backyard or small-holder premises or in the LBMS—those with a higher likelihood of contact with wild birds. Between 2006 and 2008, only five detections of LPNAI were reported in commercial poultry, one involving chickens, three in turkeys, and one in pheasants. Of the five detections, four were first detected by active sero-surveillance, and only one was detected by passive (clinical) surveillance (pheasant). If passive surveillance for AI was the only method used for detection of AI virus infections, 80% of the LPNAI detections would have been missed. Consequently, AI surveillance programs should utilize a combination of active and passive systems to increase the likelihood of detecting LPAI virus infections in poultry.

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